EFFECT OF CONTROLLED BURNING ON SURVIVAL OF FLOODWATER *AEDES* EGGS IN KENYA[1]

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ABSTRACT. The effect of controlled burning on the survival of *Aedes* mosquito eggs was evaluated in 2 distinct dambo habitats. In a dambo dominated by grasses, egg survival was 3.3% after burning compared with 43.8% in a similar dambo that was not burned. In a dambo dominated by sedges, egg survival was 0.7% after burning compared with 28.5% in a similar dambo that was not burned. Mortality of mosquito eggs appeared to be caused by high temperatures associated with the fire and not elapsed time since egg survival did not decrease with time after burning. The potential for burning to control the mosquito vectors of Rift Valley fever virus is discussed.

INTRODUCTION

Dambos, shallow depressions containing grass and sedge vegetation, serve as important habitats for the mosquito vectors of Rift Valley fever (RVF) virus in Kenya (Linthicum et al. 1983, Linthicum et al. 1984). *Aedes* spp. eggs, including those that are transovarially infected with RVF virus, are deposited in dambos and hatch after flooding during heavy seasonal rains (Linthicum et al. 1985b). After emergence, infected mosquitoes introduce the virus into susceptible animal and human hosts. Secondary mosquito vectors, such as *Culex* spp., can then maintain and amplify enzootics and epizootics (Linthicum et al. 1985b, Logan et al. 1991). Reduction or elimination of the emergence of reservoir *Aedes* spp. from dambos may prevent the introduction of RVF virus into susceptible mammalian hosts and effectively interrupt the natural enzootic cycle of the virus.

The use of insecticides to reduce mosquito populations in dambo systems during the rainy season is often impractical because of inaccessibility by ground and the high cost of aerial applications. Logan and Linthicum (1992) demonstrated only limited success in suppressing the emergence of mosquitoes from dambos using a briquet formulation of *Bacillus thuringiensis* var. *israelensis*. Linthicum et al. (1989) and Logan et al. (1990) demonstrated that pretreatment of dambos with a sustained-release formulation of methoprene may significantly reduce the emergence of floodwater mosquitoes. However, the cost of these applications on a large scale may be prohibitive for individual farmers and governments with limited resources. Wallace et al. (1990) demonstrated that controlled burning of rice fields can significantly reduce egg hatch by *Aedes taeniorhynchus* (Wiedemann). The purpose of this study was to determine the effect of controlled burning of selected dambo habitats on the survival of drought resistant floodwater *Aedes* (*Neomelaniconion*) spp. mosquitoes.

MATERIALS AND METHODS

The study site was located approximately 11 km SSE of Ruiru, Thika District, Kenya (1°12′S; 36°59′E; 1,500 m altitude) at a dambo system located on the south bank of the Kamiti River. Rainfall generally occurs in the periods April–June (long rains) and October–December (short rains) in this area. The study was conducted in October 1991 during the dry season, just prior to the onset of the short rains. Previous studies have shown that this dambo system provides suitable oviposition habitat for at least 3 potential mosquito reservoir vectors of RVF virus, *Aedes mcintoshi* Huang, *Ae. unidentatus* McIntosh and *Ae. circumluteolus* (Theobald) (Linthicum et al. 1985a, Linthicum et al. 1988). Two study areas, each measuring 100 m^2 were selected in each of 2 distinct dambo habitats. One habitat was dominated by grasses [*Digitaria abyssinica* (A. Richard) Stapf and *Cynodon nlemfuensis* Vanderyst] and is referred to as the grass dambo, and one was dominated by sedges [*Cyperus papyrus* Linn. and *C. immensus* (C. B. Clarke)] and is referred to as the sedge dambo. One study area in each habitat was experimentally burned, and the remaining unburned study area in each habitat served as a control. Experimental and control dambos were within 50 m of one another. Figures 1 and 2 show the experimental grass and sedge grass dambos before and after burning, respectively.

Study areas were subdivided into 25 evenly spaced sample grids. Within each of the 25 grids of each treatment area soil samples measuring

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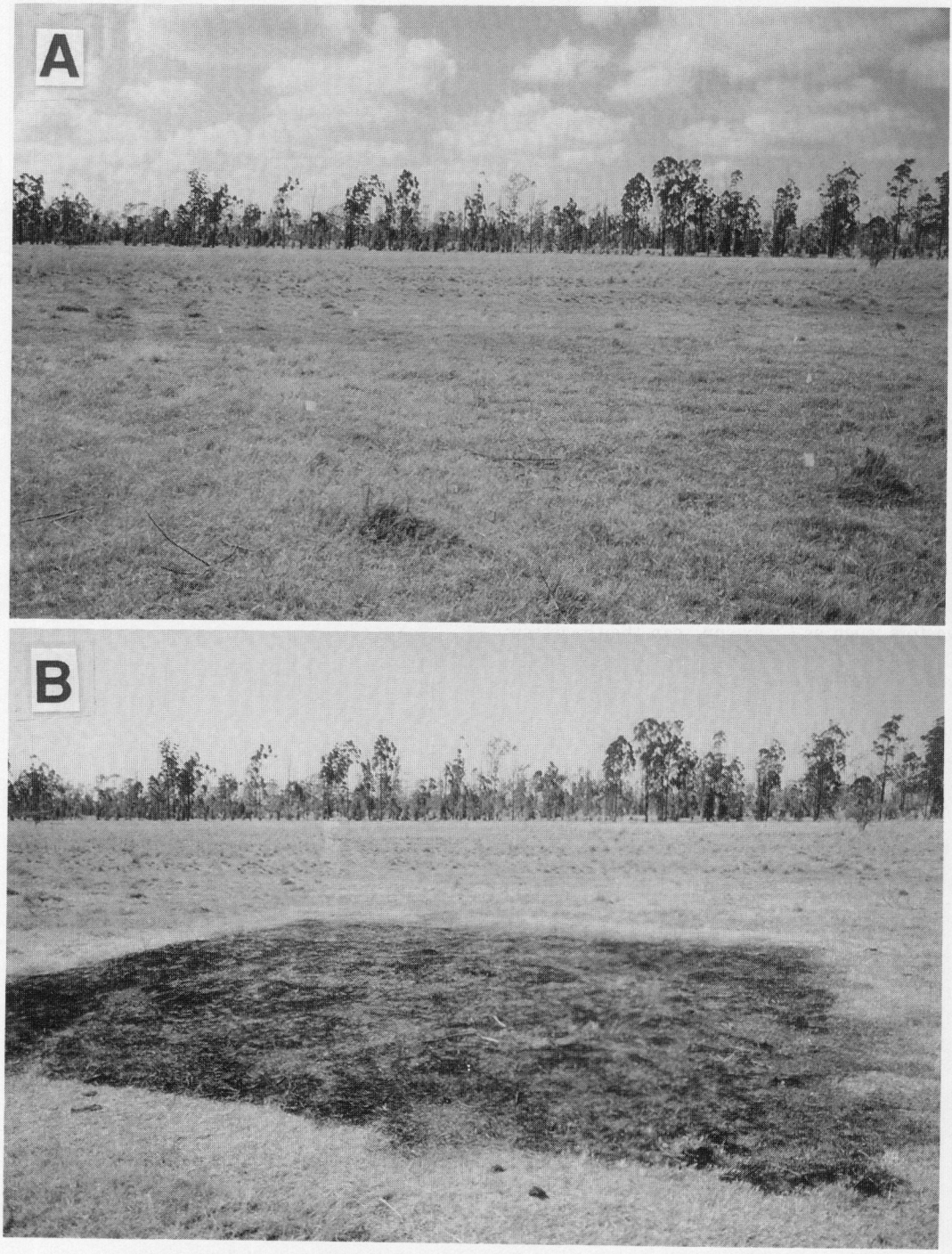

Fig. 1. Experimental grass dambo before (A) and after (B) controlled burning.

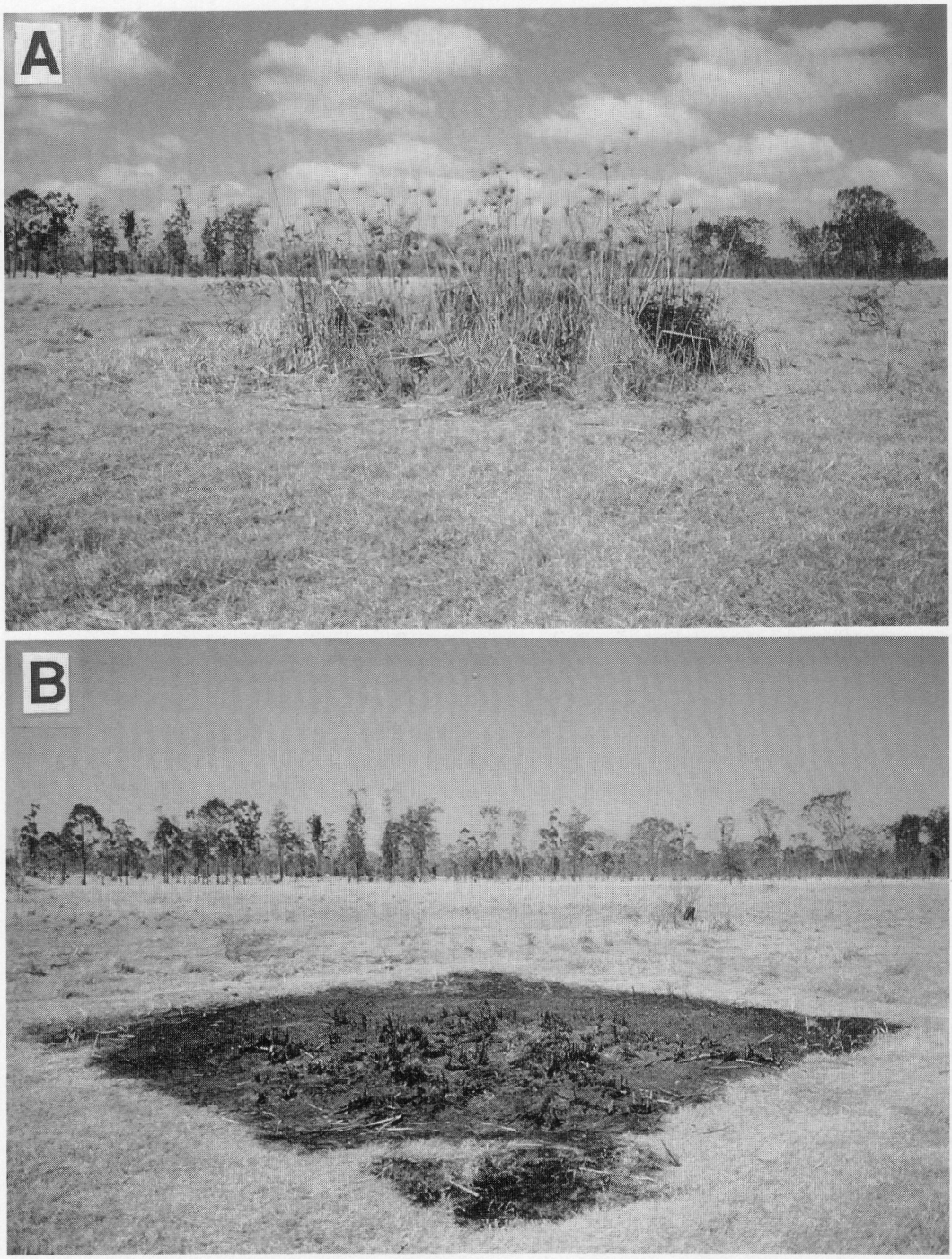

Fig. 2. Experimental sedge dambo before (A) and after (B) controlled burning.

approximately 150 mm² × 50 mm deep were collected prior to burning and twice weekly for 3 wk after burning. Soil samples were not less than 75 mm nor more than 150 mm from previous soil collection sites. Soil samples were transported to the laboratory in plastic bags where mosquito eggs were removed from soil samples using the method of Horsfall (1956). Eggs were counted and stored at room temperature on moistened filter paper in disposable 50 × 9 mm petri dishes until they were flooded for hatching.

To evaluate hatching, mosquito eggs were flooded 24–72 h after removal from soil following a method similar to that of Novak and Shroyer (1978). Thirty eggs were placed per hatching tube (5 × 30 mm). Hatching tubes were then individually immersed in 9 dram plastic vials containing dechlorinated water to which TetraMin tropical fish food (1 g/liter) was added as a deoxygenating agent. Flooded eggs were inspected 8 and 24 h after flooding, and all larvae were counted and recorded. No other attempts were made to hatch the eggs. Soil moisture, defined as percent water by weight, was measured twice weekly to determine if decreased soil moisture affected egg mortality. Five soil samples were collected as above from each treatment area. These were collected in 2 transecting lines covering the full length and width of each study area. Samples were transported to the laboratory and weighed before and after drying in an incubator at 40°C for 24 hours. Egg survival rate was defined to be the product of the mean percent of eggs recovered after the burn and mean percent hatching success of the recovered eggs after the burn.

To evaluate the effect of burning on the survival of eggs, the mean number of eggs recovered and number of eggs hatching in each of the study areas before the burn was compared with those after the burn by analysis of variance (ANOVA, $P < 0.05$), (SAS/STAT 1988). Egg recovery data were transformed to normalize it by taking the square roots of the number of eggs recovered. Hatching rate data were normalized by multiplying twice the square roots of the number of eggs collected by the arcsin of the proportion hatched (Snedecor and Cochran 1980).

RESULTS

The results of mosquito egg collections are presented in Table 1. A total of 16,682 mosquito eggs were collected. There were 14,833 eggs collected in grass dambos and 1,849 collected in sedge dambos. All eggs were identified as *Aedes* spp., predominantly (*Neomelaniconion*) spp., based on egg morphology. The mean number of

Table 1. *Aedes* spp. egg survival rate[1] after experimental burning of 2 dambo habitats in Kenya.

	Grass						Sedge					
	Experimental dambo			Control dambo			Experimental dambo			Control dambo		
	No. of eggs			No. of eggs			No. of eggs			No. of eggs		
	Avg. no. recovered	Avg. no. hatched	Survival rate	Avg. no. recovered	Avg. no. hatched	Survival rate	Avg. no. recovered	Avg. no. hatched	Survival rate	Avg. no. recovered	Avg. no. hatched	Survival rate
Preburn[2]	4,085a[3]	3,906a		817a	769a		273a	256a		280a	263a	
Post-burn[2]	430b	133b	3.3%	409a	358a	43.8%	19b	2b	0.7%	105a	80b[4]	28.6%

[1] Survival rate defined to be the product of the mean percent of eggs recovered after the burn and the mean percent hatching success of the recovered eggs after the burn.
[2] Preburn samples collected on Aug. 2 and Sept. 30, 1991; post-burn samples collected on Oct. 1, 4, 8, 11, 15 and 18, 1991.
[3] Means within a column followed by different letters are significantly different based on an ANOVA ($P < 0.05$) after transformation to provide normal values.
[4] $P = 0.03$.

eggs collected in both experimental grass and sedge dambos was significantly reduced ($P < 0.05$) after burning (by 89.5 and 93.0%, respectively). The mean number of eggs collected in the control grass and sedge dambos did not decline significantly during the period.

Prior to burning, there was no significant difference ($P < 0.05$) in the hatch rates of eggs collected from any of the dambos. Hatching success significantly declined ($P < 0.05$) in both the experimental grass dambo (from 95.6 to 30.9%) and the experimental sedge dambo (from 93.8 to 9.5%) after burning. Hatching success in the control grass dambo did not significantly decline after burning, but did significantly decline ($P < 0.05$) in the control sedge dambo from 93.9 to 76.3% (Table 1). When the reduced hatching success after burning in the experimental sedge dambo was compared with that of the control sedge dambo, the difference between them was highly significant ($P < 0.001$).

Aedes egg survival after experimental burning of the 2 habitats is shown in Table 1. After burning, egg survival in the experimental grass dambo was 3.3% compared with an egg survival of 43.8% in the control grass dambo during the same period. Overall egg survival after burning the experimental sedge dambo was 0.7% compared with an egg survival of 28.6% in the control sedge dambo during the same period.

On the day of burning, there was no significant difference in the surface soil moisture of control and experimental grass and sedge dambos. After burning, soil moisture in the experimental grass dambo was significantly less ($P < 0.05$) than the control grass dambo on all days measurements were made. Soil moisture in the experimental sedge dambo became significantly less ($P < 0.05$) than the control sedge dambo 11 days after burning and remained so through the remainder of the study. Soil moisture in both the experimental grass and sedge dambos declined until a rainfall on October 13.

DISCUSSION

Controlled burning of grass and sedge dambos resulted in both the destruction of floodwater *Aedes* mosquito eggs, as evidenced by reduced recovery of eggs and the reduced hatch rate of eggs not destroyed by the fire. Hatching success was reduced the day after burning and appeared to result from the high temperatures associated with the fire. The nearly complete destruction of eggs in the experimental sedge dambo probably resulted from the extremely hot fire and complete destruction of all surface vegetation. The significant decrease in hatching success in the control area of the sedge prohibits us from demonstrating that the observed decline in hatching success can be attributed to burning alone. However, the significant difference between the postburn hatching success in experimental and control sedge dambos indicated that burning did result in an increased reduction of egg hatching success. The fire in the grass dambo appeared to be less intense than that in the sedge dambo, and considerable surface vegetation remained in the grass dambo after burning. The fire in the grass dambo was apparently hot enough to kill large numbers of eggs, but not hot enough to destroy all of them.

Reduced surface soil moisture did not affect egg survival in this study. Even though burning resulted in a decrease in soil moisture in both grass and sedge dambos, egg mortality did not increase with time after burning. However, egg survival may have been adversely affected had soil moisture continued to decrease after October 13.

Controlled burning of floodwater *Aedes* habitats appears to effectively reduce mosquito populations. Wallace et al. (1990) demonstrated a highly significant reduction of *Aedes taeniorhynchus* emergence after burning rice fields in South Carolina. Our study shows that controlled burning can also significantly reduce *Aedes* egg survival in African dambo habitats. Controlled burning of dambos appears to provide greater suppression of floodwater *Aedes* mosquito emergence than applications of a sustained-release formulation of *Bacillus thuringiensis* Berliner var. *israelensis* (Logan and Linthicum 1992), but less suppression of *Aedes* emergence than applications of a sustained-release formulation of methoprene (Linthicum et al. 1989, Logan et al. 1990). The application of methoprene also suppresses the emergence of other vectors of RVF virus, especially *Culex* spp., that invade dambos after flooding.

Controlled burning of dambos with high densities of floodwater mosquito eggs may be an effective control strategy to reduce the emergence of reservoir vectors of RVF. The practice of burning to remove vegetation during the dry season prior to cultivation or to improve the quality and quantity of pasture vegetation is well established in many areas of Kenya (personal observation). The use of burning where applications of sustained-release methoprene formulations and other vector control strategies are impractical or prohibitively expensive might provide an effective control strategy for reducing mosquito populations to levels that will prevent the introduction of the virus into susceptible mammalian hosts.

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REFERENCES CITED

Horsfall, W. R. 1956. A method for making a survey of floodwater mosquitoes. Mosq. News 16:66–77.

Linthicum, K. J., F. G. Davies, C. L. Bailey and A. Kairo. 1983. Mosquito species succession in a dambo in an East African forest. Mosq. News 43:464–470.

Linthicum, K. J., F. G. Davies, C. L. Bailey and A. Kairo. 1984. Mosquito species encountered in a flooded grassland dambo in Kenya. Mosq. News 44:228–232.

Linthicum, K. J., C. L. Bailey, F. G. Davies and A. Kairo. 1985a. Observations on the dispersal and survival of a population of *Aedes lineatopennis* (Ludlow) (Diptera: Culicidae) in Kenya. Bull. Entomol. Res. 75:661–670.

Linthicum, K. J., F. G. Davies, A. Kairo and C. L. Bailey. 1985b. Rift Valley fever virus (family Bunyaviridae, genus Phlebovirus) isolations from Diptera collected during an interepizootic period in Kenya. J. Hyg. (Camb.) 95:197–209.

Linthicum, K. J., C. L. Bailey, F. G. Davies, A. Kairo and T. M. Logan. 1988. The horizontal distribution of *Aedes* pupae and their subsequent adults within a flooded dambo in Kenya: implications for Rift Valley fever virus control. J. Am. Mosq. Control Assoc. 4:551–554.

Linthicum, K. J., T. M. Logan, P. C. Thande, J. N. Wagateh, C. W. Kamau, C. L. Bailey, F. G. Davies and J. P. Kondig. 1989. Efficacy of a sustained-release methoprene formulation on potential vectors of Rift Valley fever virus in field studies in Kenya. J. Am. Mosq. Control Assoc. 5:603–605.

Logan, T. M. and K. J. Linthicum. 1992. Evaluation of a briquet formulation of *Bacillus thuringiensis* var. *israelensis* (H-14) against *Aedes* spp. and *Culex* spp. larvae in dambos in Kenya. Biocontrol Science and Technology. (In press).

Logan, T. M., K. J. Linthicum, J. N. Wagateh, P. C. Thande, C. W. Kamau and C. R. Roberts. 1990. Pretreatment of floodwater *Aedes* habitat (dambos) in Kenya with a sustained-release formulation of methoprene. J. Am. Mosq. Control Assoc. 6:736–738.

Logan, T. M., K. J. Linthicum, F. G. Davies, Y. S. Binepal and C. R. Roberts. 1991. Isolation of Rift Valley fever virus from mosquitoes collected during an outbreak in domestic animals in Kenya. J. Med. Entomol. 28:293–295.

Novak, R. J. and D. A. Shroyer. 1978. Eggs of *Aedes triseriatus* and *Ae. hendersoni*: a method to stimulate optimal hatch. Mosq. News 38:515–521.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods. Iowa State Univ. Press, Ames.

Wallace, F. L., M. A. Tidwell, D. C. Williams and K. A. Jackson. 1990. Effects of controlled burning on *Aedes taeniorhynchus* eggs in an abandoned rice impoundment in South Carolina. J. Am. Mosq. Control Assoc. 6:528–529.